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"Need for Speed": framework for measuring construction project pace – case of road project

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Abstract

The construction industry relies on time-to-delivery to gain competitive advantages and increase profit margins. The aim of this paper is to develop a framework for measuring construction project speed. This will be done by identifying a range of key performance indicators (KPIs). This identification of KPIs helps set a benchmark for measuring the speed of a construction project. In this paper, a conceptual framework is presented to reflect the idea behind the use of performance measurement in measuring the speed of construction projects, and then a performance measurement system tailored to a real case of a road construction project.

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Keywords: Project Speed; Construction project; Time to delivery; Performance measurement; Key performance indicators

1. Introduction

Performance measurement has been subject to a considerable amount of research and attention over the past decades. The introduction of non-financial measures has triggered much of this research; with the increase of competitive environment measuring performance has become crucial to business success (Bassioni, Price, & Hassan, 2004). The aim of this paper is to develop a framework for measuring and monitoring construction project speed at

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the operational level of the execution phase and demonstrate how it can be employed to assess the speed performance of a road construction project. This includes a review of recent literature, derivation of generic KPIs, and a practical example of how this framework operates. It is imperative to note that the paper concentrates on performance measurement for the purpose of internal management of the contractor in charge of the execution of the project and not for the evaluation by other stakeholders. Furthermore, a performance measurement framework is a general theoretical framework developed in research that can act as the basis for a company's performance measurement system, while a performance measurement system refers to the measurement system implemented by a company (Bassioni et al., 2004). Likewise, this paper will consider both a performance measurement framework and a performance measurement system in road construction projects.

2. Methodology

In order to determine the set of perceived key performance indicators for project speed, a tangible example is described in Section 4. The model helps us to superpose the scenario on a construction project and attempt to understand and apply the concept of speed on it. Once the KPIs are identified, a review of a real case of a road construction project is carried out. A literature review conducted on performance measurement in construction projects and on the concept of project speed and time vs. scope relationship in construction projects. Although many authors have written about the velocity in software development projects, nothing, to the best of our knowledge, has been said about the speed as a measurable concept in project management and how this can be measured in construction projects. We have used a road construction case to illustrate the concept. The described concept has not yet been tested or verified. The case is a road construction project; the road project is a highway that is under construction and located in Norway. In this case, the paper does not consider the construction of bridges and tunnels.

3. Theoretical Framework

A construction project is mostly initiated by the needs of the client in order to satisfy the client's requirements in terms of time, cost and quality (Lam, Chan, & Chan, 2007; Y. J. T. Zidane, Stordal, Johansen, & Van Raalte, 2015). In the construction industry, there is a tendency to measure performance in terms of time and cost (Forbes, Ahmed, & Barcala, 2002; Y. Zidane, Rolstadås, Johansen, Ekambaram, & Sriram, 2015). In 1998, a governmental report in UK had boosted organizations to move toward best practice (Department of the Environment & the Regions, 1998; Murray, Murray, & Langford, 2003; Sarhan & Fox, 2013). As a result, the UK working groups on KPIs identified a set of non-financial parameters for benchmarking projects (Dawood, Sikka, Marasini, & Dean, 2006; Sarhan & Fox, 2013; Takim & Akintoye, 2002). Regardless of the KPI agenda, there are some problems identified in the KPIs. For instance, none of the measures mentioned could identify the performance of suppliers in a project environment (Sarhan & Fox, 2013; Takim & Akintoye, 2002).

Projects behind schedule are an indicator of poor productivity and bad project performance (Chidambaram, Narayanan, & Idrus, 2012). Any delay in a project can lead to cost overruns (Sambasivan & Soon, 2007). When projects are behind schedule, they are either extended or accelerated and, therefore, incur additional cost (Chidambaram et al., 2012). Delivering projects behind schedule is an inherent risk in construction and should be treated in a similar fashion as other risks. It can be managed, shared, minimized or accepted, but must not be ignored (Asnaashari, Knight, Hurst, & Farahani, 2009). Delivering behind schedule is very costly and even a small advance in delay recovery may have substantial impact on the return of investment (ROI) of involved parties in the project, and it is important to address delay causes (Faridi & El‐Sayegh, 2006; Khoshgoftar, Bakar, & Osman, 2010; Y. Zidane et al., 2015). The best way to deal with the waste of time in project delivery is to identify causes that may lead to this (Pourrostam & Ismail, 2011; Yang, Chu, & Huang, 2013). Bubshait and Almohawis (1994) defined time as the degree to which the general conditions promote the completion of a project within the allocated duration. Naoum (1994), then Chan (1996) measured this criterion by time overrun and construction time, respectively. (Lam et al., 2007; Songer & Molenaar, 1997) and Bassioni et al. (2004) considered "on schedule" as one success criterion. Time can be managed as well as delay and speed, which was shown in much research done on concurrent engineering (Midler, 2012). Thus, the necessity of developing a framework based on generic KPIs to measure and monitor the project speed performance to be on schedule or even ahead of it. Chan and Chan (2004) state that the purpose of KPIs is to enable measurement of project performance. Langston (2013) supports that, the following attributes should be kept in mind: (1) KPIs are general indicators of performance that focus on critical aspects of outputs or outcomes. (2) Only a limited, manageable number of KPIs is maintainable for regular use (too many or too complex KPIs can be time and resource consuming). (3) The systematic use of KPIs is essential as their value is almost completely derived from their consistent use across projects. (4) Data collection must be made as simple as possible. (5) KPIs should be generic and able to be used on every project. (6) For performance measurement to be effective, the KPIs must be widely accepted, understood and owned. Cox, Issa, and Ahrens (2003) defined key performance indicators in construction as compilations of data measures used to assess the performance of a construction operation. They divided them into qualitative and quantitative performance indicators, where quantitative are the most commonly accepted performance indicators since they can be physically measured by dollars, units, or man-hours. KPIs are classified into three conceptual phases of a construction project: pre-construction, construction, and post-construction because project success criteria change over time in each phase (Dawood et al., 2006; Sarhan & Fox, 2013). Our concern in this paper in more about developing KPIs for measuring, monitoring and controlling project speed in the construction phase. It may be subjective to some extent, as most of the basic data for the performance measurement are qualitative and difficult to convert into numbers for calculating the values of our KPIs. Speed is one of the six success KPIs for a construction project (Langston, 2013). In our case, speed should be considered separately and techniques for dealing with it identified, ensuring success of construction projects with regard to their time management.

4. The "Need for Speed" Measurement, Monitoring and Control Systems in Construction Projects

To be more practical, an example provided in this section describes a trip to the airport (Figure 1), which must end safely in thirty minutes and without the driver being fined. The distance to the airport is 50 km; the time frequently required for reaching the airport from our location is at least sixty minutes. So how is it possible to reach the airport in half the time? The required average speed for reaching the target (arrive in thirty minutes) is 100 km/h.

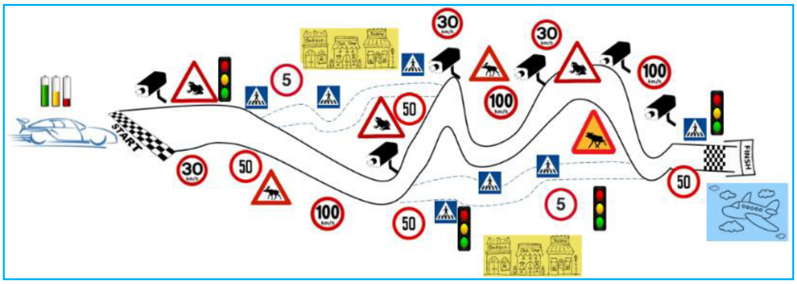

Fig. 1. Need for Speed

The car maximum speed is 200 km/h. That is not the most important issue; the most important aspect is the acceleration of the car. It can accelerate from 0 km/h to 110 km/h in just one and a half second, and the speed can be reduced from 110 km/h to 0 km/h in just three seconds. The road is full of obstacles, which is the external environment (e.g., speed cameras, pedestrian crossings, traffic lights, speed limitation signs, etc.). However, the car is equipped with a very sophisticated GPS system that can calculate in each second the remaining time before reaching the target based on the actual speed of the car. The driver is experienced, healthy and reflective, and he knows the path to the airport very well, including the pitfalls (i.e., where the speed cameras are located, when traffic jams may occur in the shortcuts, etc.), and he knows the potential opportunities for reducing the time of the trip. All these parameters and indicators will enable the driver to reach the target safely and without being fined in half the time than what is usually required, based on use of the GPS system. Using merely the GPS system to control the speed in reaching the milestone can never be the case; it is just a tool that supports the whole (i.e. the experienced driver, his knowledge of the trajectory and his car, the car quality and performance, etc.). The same can be said about projects and project management; the framework suggested in this paper is a tool for measuring and monitoring the speed of the delivery but not the single key success factor if all the other preconditions should not be available.

5. Project Speed Performance Measurement Framework

Langston (2013) has identified six KPIs that articulate successful project delivery. These are complexity, impact, innovation, value, efficiency and speed. In this paper, our concern is more about the speed (Figure 2.a.), which is the relationship of scope to time, where Langston (2013) has defined it as “the ratio of scope over time, this KPI is another that should be maximized. Speed is a function of Project Procurement Management, namely outsourcing strategies and parallel supply chains. Scope is treated as an output and time as an input, so the more utility provided per unit of time the faster is the delivery process”. Therefore, in our case we identify the most vital key performance indicators for the project speed. The average speed is the minimum production speed required for ending execution as planned. Referring again to the trip example, if we have to travel 50 km, and we need to complete the trip in 30 minutes, the average speed should be minimum 100 km/h. If we are required to build a 50-km road (two lanes) in 300 working days, our production speed should be at least 0.17 km/day.

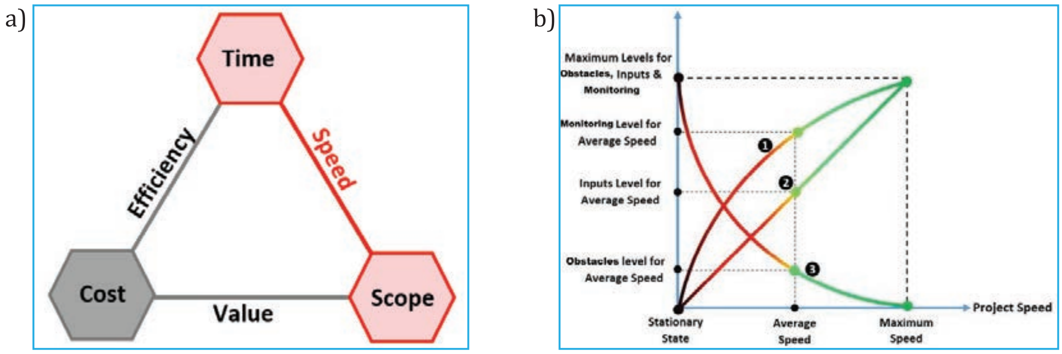

Fig. 2. (a) Iron Triangle (Langston, 2013); (b) Framework of Project Speed vs. Monitoring, Inputs and obstacles

From the previous definition (Langston, 2013) of project speed, the first KPI identified is inputs, in other words all the necessary materials, designs, documents, decisions, utilities, instruments, resources and human resources needed to accomplish a certain progress within a unit of time in pointed time within the execution phase. The inputs can be categorized as soft inputs such as decisions, designs, etc., or hard inputs, such as materials, instruments, etc. The level of inputs is directly proportional to project speed (see curve number 2 in Figure 2.b). The more the inputs are increased per unit time, the more possible it is to increase the project speed. The level of inputs is determined by the minimum level of all inputs (see Figure 3 as an example; the level of inputs is equal to the level of input I_7). In other words, whatever is the higher level of all inputs, if one of them is low, then the total level of inputs will depend on the lowest level of all inputs independently. This means that the inputs level KPI is equal to the lowest input level of all inputs.

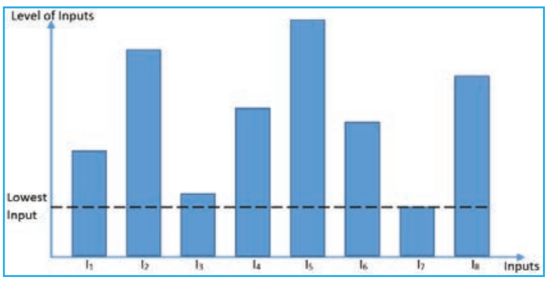

Fig. 3. Example of level of all needed inputs for a block activity in a given time.

The second KPI is monitoring, as in driving car. We cannot keep the speed at more than 80 km/h in sharp bends or on a curvy road, or drive slower than 50 km/h on a highway where the minimum speed is 80 km/h. There are road signs one must observe and an environment surrounding the car to consider, let us say i.e. the state of the driver (tired, sleepy, etc.), other cars, animals, pedestrians, rain, snow, etc. The same can be said about the monitoring KPI: if the project has no qualified human resources with enough knowledge and skills to do their tasks, they will keep doing mistakes and errors, and that will lead to rework, accidents and changes. In this case, the project management team will lose some of the project speed control. Nevertheless, if we have experienced and skilled team members, a good HSE plan to follow, enough information for completing each task and integrated teams, the project management team will have a good monitoring and control of the project progress, thus being able to sustain a good speed. The monitoring KPI is also directly proportional to project speed (see curve number 1 in Figure 2.b). The more we achieve good monitoring, the more we control, and consequently we will be able to increase the project speed more.

The last KPI is obstacles. These are risks, barriers, ambiguities, difficulties, major forces, bottlenecks and time-thieves that can hinder the progress (Y. J. T. Zidane, Johansen, Andersen, & Hoseini, 2015). Opportunities are considered to be the maximum positive side of obstacles. In other words, when we have no obstacles in a given time, then that should be considered as an opportunity to increase the project speed.

Table 1. Project Speed KPIs and needed parameters to calculate them.

KPIs	Parameters	Type and Effect
Speed monitoring	Changes Rework Errors and Mistakes	Quantitative. Negative effect to project speed, causes delay and extra costs
	Accidents	Quantitative. Negative effect, causes delay and extra costs and even may harm employees.
	HSE	Qualitative. Positive effect decreases accidents, thus save time and costs
	Skills and Knowledge Experiences Information Integration	Qualitative. Positive effect save time and costs
Speed Inputs	Materials Utilities Human resources Designs decisions	Quantitative. Positive effect in case of high inputs level, the more procurement are done in advance, the resources prepared, the decisions are made, the more the project speed will be higher
	interdependencies	Qualitative, depends on the degree of integration among the project teams, the more integration, the more easy to manage interdependencies.
Obstacles	Risks Difficulties and Pitfalls Ambiguities Bottlenecks Time-thieves Major forces	Qualitative. Negative effect, the more intense, the more delays and costs
	Opportunities	Qualitative. Positive effect, occurs when all above pitfalls are absent

The Table 1 summarizes the parameters that stimulate the three KPIs relating to the project speed. Of course, most of them are subjective since they are hard to measure, except when it comes to speed inputs, where most are measurable.

We should also draw attention to these parameters and mention that they are interrelated to high extent. For example delays in making decisions in the inputs KPI may be due to a lack of information and experience; that parameter belongs to the monitoring KPI, and so on (Y. J. T. Zidane, A. Johansen, et al., 2015).

6. The Performance Measure Framework Tailored to the Case

To give more credibility to the framework, a case of a road construction project is considered (excluding bridges and tunnels) to illustrate the performance measurement system. There are typically six layers in a Norwegian road (Figure 4.b). Each layer is considered to be a block activity. Let us consider the bottom layer, the subgrade. In order to realize the subgrade layer, one must do block activity 1 (Figure 4.a), which is called a "cut and fill" in road construction projects. The production is measured in cubic meters.

a) b)

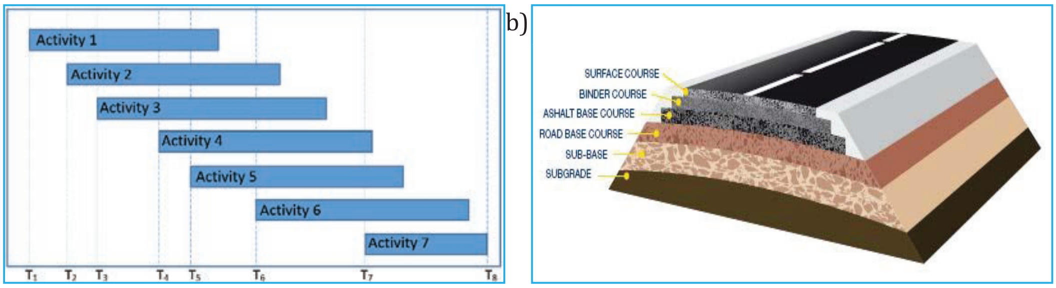

Fig. 4. (a) Gantt chart for construction phase; (b) Road different layers

For instance, in block activity 6, which is the upper layer, production is measured in terms of meters; the same can be said about block activity 7, painting separation lines on the road. Thus, in order to measure the total speed of the project we need to measure the speed of each block activity separately. The unit of speed used in the performance measurement system is cubic meter / day, square meter / day and meter / day, depending on the block activity. The block activities in road construction projects are in sequence, for example, if we achieved sufficient progress in the "cut and fill" activity, the teams can start putting the sub-base, etc. A delay in one block activity will cause delay in all the others. The same applies if time is saved and one is ahead of schedule.

Using the framework in the previous chapter, the road construction case and the guidance of the book "Performance Measurement Explained: Designing and Implementing your State-of-the-Art System" (Andersen & Fagerhaug, 2002) and also that of Wolk, Dholakia, and Kreitz (2009), we come up with the performance measurement system interface example shown in Figure 5.

For the tab showing block activity six, this block activity will be triggered when there is enough accumulated progress from all previous block activities. The same principle applies to all the block activities from the second until the seventh tab. The first activity is triggered by the decision to start construction of the road. There is a tab for each block activity, as the speed of each block activity is measured separately. The lowest fourth level is the basic data for performing calculation for the monitoring, inputs and obstacles KPIs. Once completed, these three KPIs will in turn constitute the input for determining the value of the construction speed. To meet time to delivery (TTD) or, in other words, the planned time to complete the block activity, we need the speed to be at least average. To keep the speed average based on the three KPIs, the speed monitoring KPI should be on the indicator in the state "Control" or higher, the speed inputs KPI should be on the indicator in the state "Min Inputs" or higher, and the last KPI, pitfalls, should be on the indicator in the state "Few obstacles" or higher.

The performance measurement system in Figure 5 is based on daily measuring. This enables us to know the real speed of the production and the accumulated or lost days within the block activity (Figure 5, level 2, the indicator on the left-hand side) and also within the whole construction phase (Figure 5, level 1, the indicator on the left-hand side). The indicators in the middle of level 1 in Figure 5 show the percentage of the completed production, and the consumed number of days to produce that percentage. The tab in Figure 5 is the same for all seven activities; the difference is in the unit used (m/day, m^2/day and m^3/day). For the main tab "Total Project Speed", it is a summary of total progress, the accumulated or lost days, where there is need for improvement, the cause of delay (e.g. one of the inputs) and any indicators that allow the project team to take immediate action for improvement to increase the construction speed in order to hit the target.

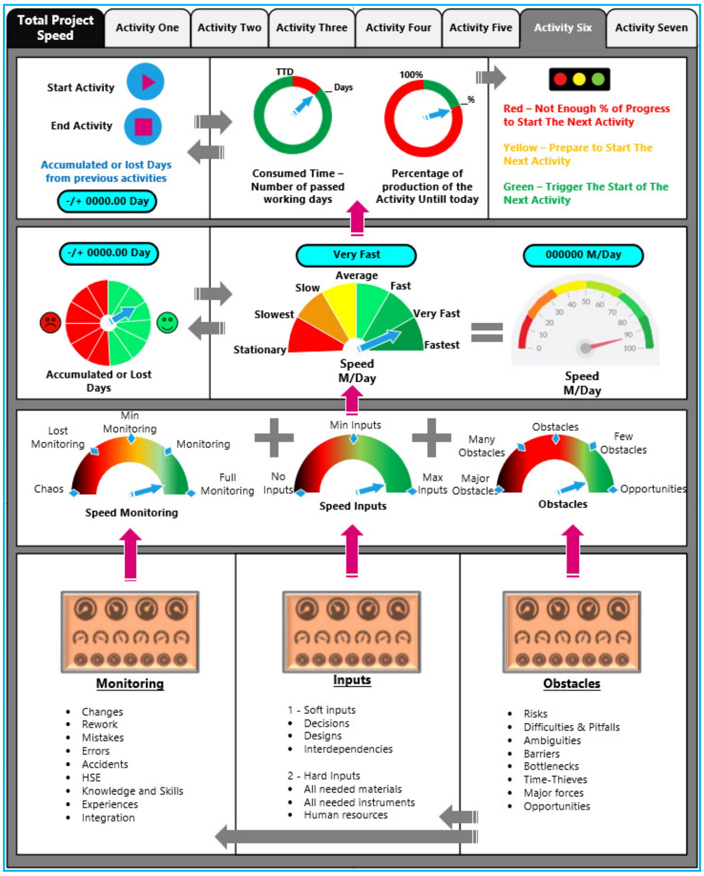

Fig. 5. Example of Possible Project Speed Performance Measurement System

Finally, we should mention that all the departments within the project should feed this performance measurement system as they are all involved, e.g., the procurement department, the quality and risk management department, functional departments, etc. This feeding can be done using a systematic approach by "big data" collection; by using sensor information and production data from several existing systems (e.g. GPS, internal administrative IT systems, etc.). Thus, the performance measurement system is not required to rely on information from all the departments (which tend to neglect reporting or submit the data very late). A systematic "big data" collection will make it possible to design a live performance system for speed in construction projects.

7. Conclusions

Time, delays and speed in construction projects can be managed. Therefore, a project speed framework for the construction phase has been developed based on a set of KPIs. Even if two of the KPIs are subjective, as they are difficult to measure, the framework can trigger a real consideration for measuring construction speed. Being able to manage the speed of project productivity in real time and on a daily basis will enable the project management team to meet the targets regarding the project's time to delivery. Further work is needed on the parameters feeding the control and pitfalls KPIs, and on finding ways of making their inputs measurable. We believe that development of a performance measurement system for project speed will revolutionize the construction industry.

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